LOW-COST, LIGHT-WEIGHT, INTERNAL HUMIDIFIED PEM FUEL CELL

A.J. Appleby, Omourtag A. Velev,
Serguey Gamburzev, and Supramaniam Srinivasan

Center for Electrochemical Systems and Hydrogen Research
Texas Engineering Experimental Station
Rm. 238 WERC Bldg.
Texas A&M University System
College Station, TX 77843-3402, USA

Introduction

Widespread introduction of fuel cell technology could yield many benefits for the United States; chief among them are significant fuel savings, increased energy security, and greatly reduced environmental emissions. Fuel cells are considered strong candidates for transportation applications. However, for fuel cell technology to be considered an alternative to conventional automotive power plants, the fuel cell stack, when combined with the fuel processor and other balance-of-plant components, must be competitive in performance and cost with the equivalent internal combustion engine (ICE) propulsion system.

Fuel cells for transportation require high power density (minimum weight and volume per unit power output), capability for rapid start-up (in seconds), the ability to respond to frequent high-percentage load changes, and low cost. Tradeoffs between the cost and performance of the various components are possible. As fuel cell vehicle development programs progress, the appropriate tradeoffs will be more clearly defined. Preliminary development goals were established in the program solicitation (DE-RA08-95CE50384) which resulted in this contract. They are as follows: fuel cell stack power density, 800 W/l; fuel cell stack specific power, 800 W/kg; and potential manufacturing cost, $30/kW.

Because PEM fuel cells can generate partial power at ambient temperature they offer greater potential than other fuel cell technologies for meeting the challenges of transportation applications. Although it takes several minutes for a PEM fuel cell to reach its operating temperature (approximately 80 °C), a vehicle may be started, then operated at better than half power, without a lengthy warm-up period. In today's PEM fuel cell, the operating part of the stack, i.e., the membranes and electrodes, contribute very little to the total stack weight; whereas components such as bipolar plates, end plates and associated hardware contribute the most weight. Thus there is great potential and incentive for reducing the weight of the fuel cell stack in its present configuration, which will reduce materials cost. Cost reductions are also expected from continued progress in reducing the electrode platinum loadings and from innovative fabrication methods as well as from the economics of large-scale production.

The objective of this contract is to advance PEM fuel cell technology for automotive applications. This research is intended to develop low-cost, light-weight PEM fuel cell components having the potential to reduce manufacturing costs to achieve the preliminary development goals stated above. This abstract presents preliminary data, since work under DOE contract No. DE-AC08-96NV11985 only started in June, 1996.

Experimental Procedures

Experiments have been carried out in 5 and 50 cm^2 PEMFC single cells at different temperatures and atmospheric pressure with H_2/air as reactants. The fuel cell electrodes were prepared *in-house* with Pt supported on Vulcan XC-72 carbon electrocatalysts (E-TEK Inc., Natick, MA). The proton exchange membranes, Nafion® 112 (DuPont de Nemours, Wilimington, DE) and GORE-SELECT™ (W.L. Gore and Associates, Elkton, MD), were used as received. The reactant utilization in the 50 cm^2 cell was 95 % for hydrogen and 50 % for oxygen at all current densities.

Results and Discussion

The best performance to date, achieved with low loaded electrodes, is illustrated on Figure 1. This test was with a 5 cm^2 cell and humidified reactants at atmospheric pressure.

The effect of scale-up on performance is illustrated on Figure 2. The linear region in the potential vs. current density plot extends to a current density of 1000 mA/cm^2. The performance in the larger cell is lower and at 0.7 V the current density is 200 mA/cm^2. The total electrocatalyst loading for this cell was 0.6 mg Pt/cm^2.

Other important and expensive components of the state-of-the-art PEMFCs are the bipolar plates. Currently they are made from machined or molded graphite, which is very difficult to make both very thin and non-porous. This significantly lowers the power density of the overall system. Replacing the graphite is not an easy task. Any potential replacement material must satisfy several conditions - high electronic and thermal conductivity, high chemical stability, high mechanical strength and very low porosity. Several materials have been tested to determine their chemical stability and their effect on fuel cell performance. The results from these experiments are summarized on Figure 3.

Cells with stainless steel, grafoil and aluminum plates have performance comparable to the performance of a cell with graphite end plates. Aluminum is not stable and corrodes very quickly at the high potential of the cathode in the presence of water and oxygen. The formation of oxide/hydroxide layer leads to rapid performance decay, as is illustrated on Figure 4.

Stainless steel can be used as a material for bipolar plates in PEMFC, since it is corrosion resistant and has the necessary electronic and thermal conductivity. As Figure 5 shows, the cell performance deteriorates very slowly over a 1000 hour test period.

Gold plating of the stainless steel adds further stability of the surface and the performance deterioration can be reduced as is illustrated on Figure 6. The dependence of the current on time at two current densities is presented. The stability of the cell potential at low current density is indicator that there are no impurities which might poison the electrocatalyst activity. In contrast the stability of the membrane and the water rejection characteristics of the electrodes are tested at high current density.

Work to be Conducted between October 1996 and June 1997

- Investigation of ultra-low platinum loading electrodes, advanced membranes, and internally-humidified membrane electrode assembly (MEA) concepts;
- Development of light-weight, low-cost bipolar plates and end plates;
- Investigation of novel concepts for integration of water and thermal management;
- Performance analysis and conceptual design of full-scale stack and recommendations for further development.